Water Quality Modeling of Golden Gate Canal System

Abstract

A water quality model was developed to simulate the eutrophication processes in the Golden Gate Canal System, Collier County, Florida. The model was built in MIKE11/ECOlab software by DHI. The MIKE11 module was used to solve the hydrodynamic and advection-dispersion transport processes in the canals. ECOlab is a template that allows simulations of the sink and sources in the advection-dispersion equations. For this application, the equations and parameters in the ECOlab template were made consistent with the USEPA Water Quality Analysis Simulation Program (WASP). The runoff and baseflow volumetric rates in the canals were extracted from a regional MIKESHE/MIKE11 model for Collier County, from which the MIKE11 model for the Golden Gate area was telescoped. The simulation period was chosen as one year (i.e., from June, 2003 to June, 2004), where the annual precipitation rate is close to the historical average. The model results were compared to the observation data measured during this period (and also measured in other years) in order to adjust the eutrophication-related model parameters. The calibrated model was used to display the spatial and temporal variability of the water quality constituents. Two sensitivity tests were conducted by varying the runoff concentrations in order to evaluate the effect of the runoff loading on the dissolved oxygen concentration in the canal system. Results will be used to help develop the County's Basin Management Action Plan is compliance with the State of Florida Total Maximum Daily Load Program.

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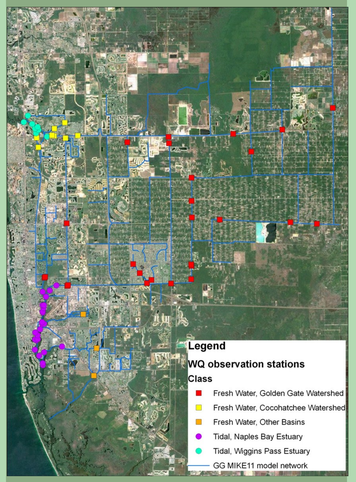
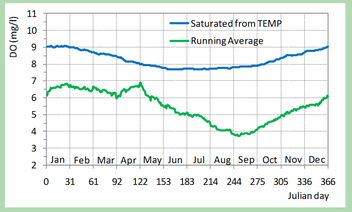
Observation Data

There are a total of 73 surface water WQ observation stations inside (and close to) the canal network of the Golden Gate (GG) Watershed area, which contain a total of 2210 measurements in the period from years 2000 through 2009.



In order to have an idea of the seasonal trend and range of variation of the WQ constituents of interest, all station data available was plotted in a one year period by using a Julian-Day representation.

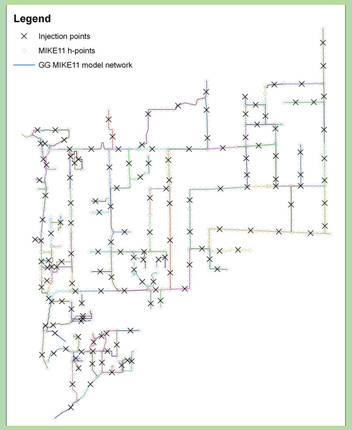
In the included figure, the saturated Dissolved Oxygen (DOsat) concentration in fresh water estimated from the seasonal averaged water temperature is compared to the seasonal averaged DO. From those curves, it is clear that the seasonal trend in the temperature could not solely explain the minimum in the observed DO values around September.



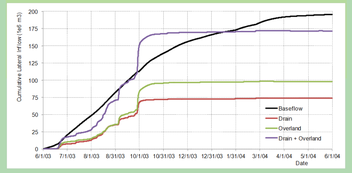
HD Model Setup

The simulation period for the WQ modeling was selected from June 1, 2003 to June 1, 2004. During this period, the cumulative rainfall is 55.9 inches, which is close to the historical annual rainfall in the area.

The hydrodynamic (HD) MIKE11 component for the GG watershed model was telescoped from the calibrated MIKE SHE - MIKE 11 model for the Collier County area. The MIKE11 telescoped model was also decoupled from MIKE SHE in a way that the lateral water inflows from the MIKE SHE components (overland, drainage, and saturated zone) at each MIKE11 h-point were extracted from a previous MIKE SHE - MIKE11 simulation. Finally, the lateral inflows were lumped together by branch segments, here labeled as "pools".



The cumulative lateral inflow into all MIKE11 h-points from the different components during the simulation period is presented in the figure below. According to the parent model, the annual runoff (Drain and OL) volume is comparable to the annual baseflow volume, but the last occurs also during most part of the dry season.



WQ Model Setup

The water quality (WQ) MIKE11 - ECOlab model uses the volumetric flow resulting from the HD component to estimate the advective - dispersive (AD) transport of the constituents. The processes involving the constituents and representing sink and sources in the AD equations are considered through ECOlab.

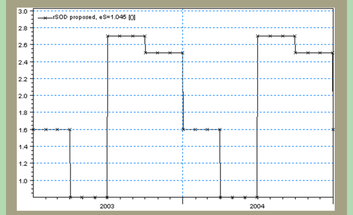
DHI provides several pre-developed ECOlab templates that contain Eutrophication processes. However, in this work, a new template was developed with equations and parameters based on the Eutrophication module in the version 6 of WASP.

The nine (9) states variables in the ECOlab template are listed in the Table below.

No.	Symbol	Description
1	NH4	Ammonia
2	NO3	Nitrate
3	PO4	Phosphate
4	PHYT	Phytoplankton Carbon
5	CBOD	Carbonaceous BOD
6	DO	Dissolved Oxygen
7	ON	Organic Nitrogen
8	OP	Organic Phosphorus
9	Sal	Salinity

The ECOlab template has also fifty three (53) constant input parameters, seven (7) forcing parameters, thirty two (32) auxiliary variables, and twenty nine (29) processes.

One of the key forcing parameters is the sediment oxygen demand that was assumed quarterly varying as shown in the graph below.



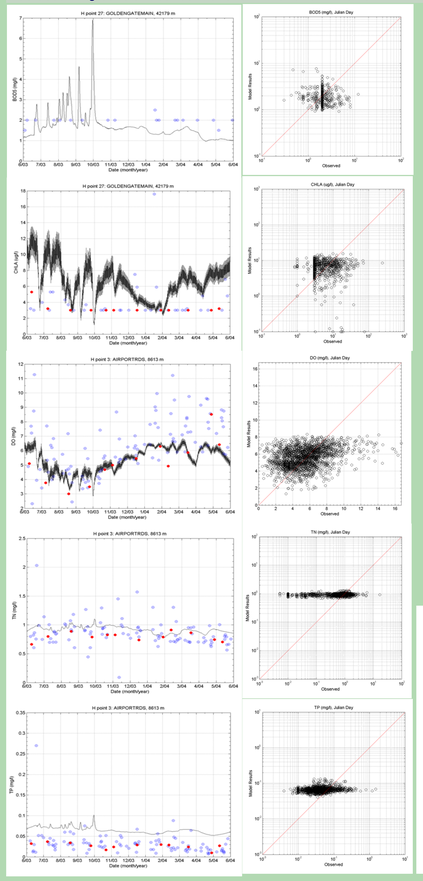
Boundary conditions concentrations in lateral inflow from runoff were assumed constant and dependent on the landuse classification close to the MIKE11 h-points. A removal efficiency was assumed in urban landuses.

In the case of the boundary conditions concentrations in lateral inflow from baseflow they were assumed constant and uniform. In both cases, the concentration values were adjusted during the calibration.

Results – Plots

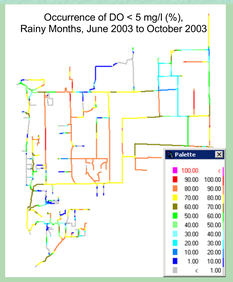
The time series plots of observed vs. simulated concentrations after the calibration are presented below at the downstream end of the Golden Gate Watershed. Black lines are model results, red disks measurements during the simulated year, and blue circles measurements in other years. In general, the plots at observation stations show good agreement between the model results and the observation data.

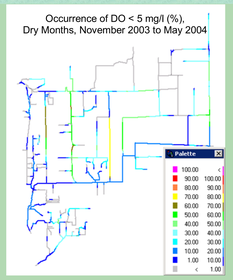
The scatter plots including all observed vs. simulated concentrations show that the line "Y=X" runs though the center of the cloud of points in most of the cases, which is an indication of low systematic errors. In most of the scatter plots, though, the cloud of points is elongated in the X-axis direction, which implies that the model is not capturing the entire range of variability of the constituents. This may be a consequence of assuming uniform and constant concentrations in the groundwater inflows, as well as assuming constant concentrations in the runoff inflows.



Results - Maps

Florida's Surface Water Quality Standard (Chapter 62-302, F.A.C) states that, for Class III freshwater waterbodies, the DO concentration "Shall not be less than 5.0 (mg/L). Normal daily and seasonal fluctuations above these levels shall be maintained". There are only a few gray-colored branch segments from the included maps that may satisfy this criterion. DO concentration in all other branch segments falls below the 5 mg/l limit, according to the model results. The number of occurrences DO < 5mg/l is higher in the rainy months with respect to the dry months.





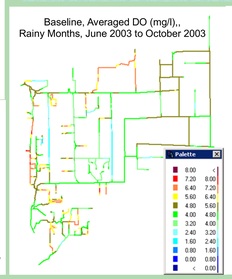
Sensitivity Tests

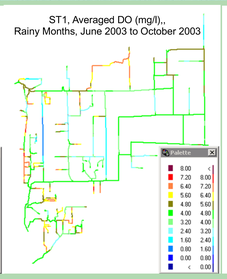
The first sensitivity test (ST1) was conducted to evaluate the influence of the DO runoff concentration in the model results. The runoff DO/DOsat fraction was decreased from 80 to 22 %. This is effectively a change in the runoff DO concentration during the rainy months from 6.15 to 1.7 mg/l, i.e., around a 4.45 mg/l decreasing. These two DO concentrations correspond to a weighted-area value by landuses and to the value in wetlands, respectively.

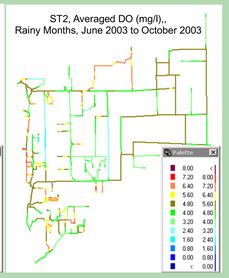
As a result, the DO concentration during rainy months decreased 0.33 mg/l in average in canals at observation stations, which represents only 7 % of the decrease of 4.45 mg/l in runoff DO concentration. The runoff DO concentration change is reduced when entering in the canals in 45 % because of the presence of baseflow and in 47 % because of the DO processes. This small average change of 0.33 mg/l is in agreement with DO increase in some branches during the rainy months (see maps below), which is typically not higher than one step in the color scale with 1 mg/l intervals. Therefore, the result from this sensitivity test does not support the hypothesis that the low DO concentrations might be caused by the low DO concentrations from wetland runoff inflows.

The second sensitivity test (ST2) was conducted to evaluate the influence of the anthropogenic loading in the model results. Specifically, all agricultural and urban landuses were set to Forest/Rural/Open while estimating the runoff concentrations for BOD and nutrients.

As a result, the DO concentration during rainy months decreased 0.15 mg/l in average in canals at observation stations. This small average change of 0.15 mg/l is in agreement with DO increase in some branches during the rainy months (see maps below), which is typically not higher than one step in the color scale with 1 mg/l intervals. Therefore, the result from this sensitivity test does not support the hypothesis that the low DO concentrations in the canals might be caused by the anthropogenic increase in BOD and nutrients loading.







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Satinleaf tree island, Shark River